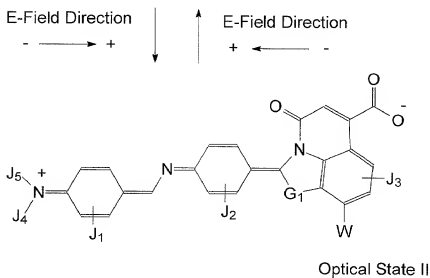
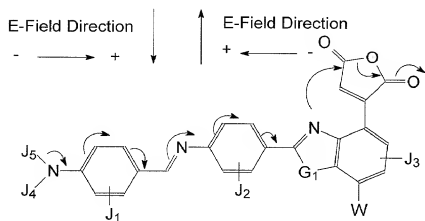
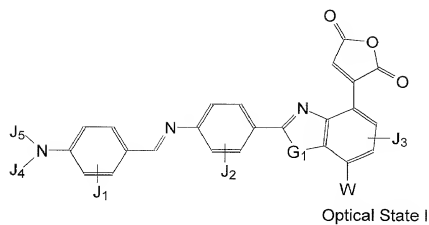


CLAIMSWhat Is Claimed Is:

- 5           1. A switchable medium for a visual display comprising an electric field activated molecular system configured within an electric field generated by a pair of electrodes, said molecular system having an electric field induced band gap change that occurs via a reversible or irreversible change of extent of the electron conjugation in the molecule via chemical bonding change to change the band gap, wherein in a first state,  
10       there is substantial conjugation throughout the molecular system, resulting in a relatively smaller band gap, and wherein in a second state, the substantial conjugation is destroyed, resulting in a relatively larger band gap.
2. The switchable medium of Claim 1 wherein said change of substantial conjugation is accomplished by charge separation or recombination accompanied by increasing or decreasing molecular electronic state localization.  
15
3. The switchable medium of Claim 2 wherein said molecular system comprises



where:

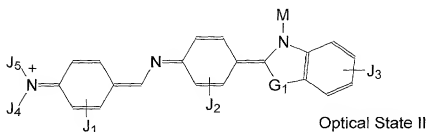
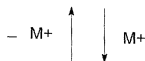
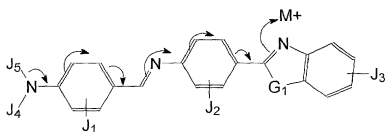
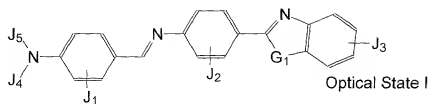
- 5 J<sub>1</sub>, J<sub>2</sub>, J<sub>3</sub>, J<sub>4</sub> and J<sub>5</sub> are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects,

and steric effects, said tuning groups being selected from the group consisting of (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl, Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

- 5           G<sub>1</sub> is a bridging group to connect at least two conjugated rings to achieve a desired chromophore, said bridging group selected from the group consisting of (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons; and

- 10           W is an electron-withdrawing group for tuning reactivity of the maleic anhydride group of said molecular system, which enables said molecular system to undergo a smooth charge separation or recombination upon application of said electric field, said electron-withdrawing group selected from the group consisting of (a) carboxylic acid and its derivatives, (b) nitro, (c) nitrile, (d) ketone, (e) aldehyde, (f) sulfone, (g) sulfuric acid and its derivatives, (h) hetero atoms selected from the group consisting of F, Cl, Br, N, O, and S, and (i) functional groups with at least one of said hetero atoms.

4. The switchable medium of Claim 2 wherein said molecular system comprises



where:

- J<sub>1</sub>, J<sub>2</sub>, J<sub>3</sub>, J<sub>4</sub> and J<sub>5</sub> are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects, and steric effects, said tuning groups being selected from the group consisting of (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl, Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

- G<sub>1</sub> is a bridging group to connect at least two conjugated rings to achieve a desired chromophore, said bridging group selected from the group consisting of (a) het-

ero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons; and

5  $M^+$  is selected from the group consisting of transition metals, their halogen complexes,  $H^+$ , and Lewis acids.

10 5. The switchable medium of Claim 1 wherein said change of substantial conjugation is accomplished by change of extent of the conjugation of the molecular electronic states via charge separation or recombination and  $\pi$ -bond breaking or making.

15 6. The switchable medium of Claim 5 wherein said molecular system includes a C-O bond of a lactone that is labile enough and can undergo a bond breaking or making in the presence of an applied electric field, thereby inducing said change of the electron conjugation via chemical bonding change to change the band gap.

7. The switchable medium of Claim 6 wherein said molecular system comprises



where:

Q is a connecting unit between two phenyl rings and is selected from the group consisting of S, O, NH, NR, hydrocarbon, or substituted hydrocarbon;

Con<sub>1</sub> and Con<sub>2</sub> are optional connecting units between one molecule and another molecule or between a molecule and a solid substrate, said connecting units independently selected from the group consisting of: (a) hydrogen (utilizing a hydrogen bond), (b) multivalent hetero atoms selected from the group consisting of C, N, O, S, and P, (c) functional groups containing said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

R<sub>1</sub> and R<sub>2</sub> are spacing groups, used to provide an appropriate 3-dimensional scaffolding to allow molecules to pack together while providing rotational space for a part of the molecule, said spacing groups being independently selected from the group consisting of: (a) hydrogen, (b) saturated or unsaturated hydrocarbons, and (c) substituted hydrocarbons;

J<sub>1</sub>, J<sub>2</sub>, J<sub>3</sub>, and J<sub>4</sub> are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects, and steric effects, said tuning groups being selected from the group consisting of (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl, Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

G<sub>1</sub> is a bridging group to connect at least two conjugated rings to achieve a desired chromophore, said bridging group selected from the group consisting of (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons; and

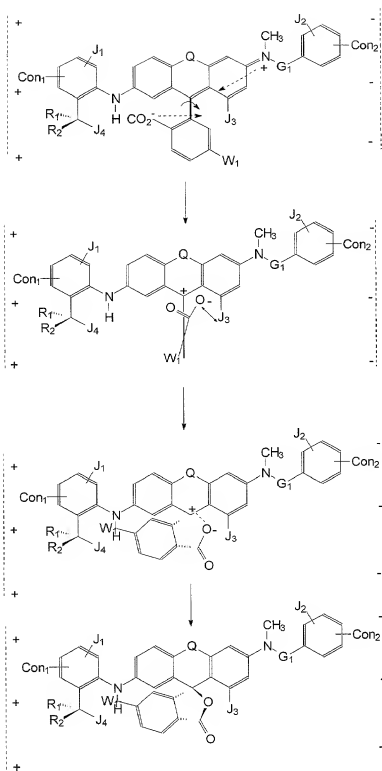
W is an electron-withdrawing group for tuning reactivity of the maleic anhydride group of said molecular system, which enables said molecular system to undergo a smooth charge separation or recombination upon application of said electric field, said electron-withdrawing group selected from the group consisting of (a) carboxylic acid and its derivatives, (b) nitro, (c) nitrile, (d) ketone, (e) aldehyde, (f) sulfone, (g)

sulfuric acid and its derivatives, (h) hetero atoms selected from the group consisting of F, Cl, Br, N, O, and S, and (i) functional groups with at least one of said hetero atoms.

8. The switchable medium of Claim 6 wherein said molecular system comprises

107900 9345432  
50933456 004701





where:

Q is a connecting unit between two phenyl rings and is selected from the group consisting of S, O, NH, NR, hydrocarbon, or substituted hydrocarbon;

Con<sub>1</sub> and Con<sub>2</sub> are optional connecting units between one molecule and another molecule or between a molecule and a solid substrate, said connecting units independently selected from the group consisting of: (a) hydrogen (utilizing a hydrogen bond), (b) multivalent hetero atoms selected from the group consisting of C, N, O, S, and P, (c) functional groups containing said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

R<sub>1</sub> and R<sub>2</sub> are spacing groups, used to provide an appropriate 3-dimensional scaffolding to allow molecules to pack together while providing rotational space for a part of the molecule, said spacing groups being independently selected from the group consisting of: (a) hydrogen, (b) saturated or unsaturated hydrocarbons, and (c) substituted hydrocarbons;

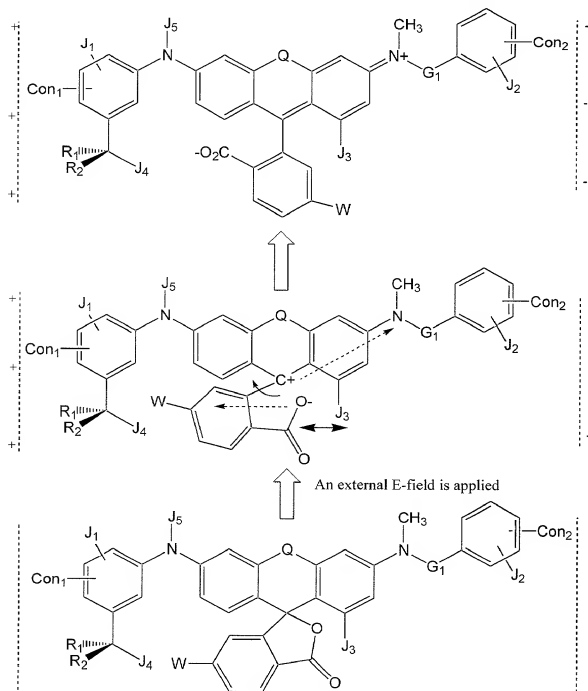
J<sub>1</sub>, J<sub>2</sub>, J<sub>3</sub>, and J<sub>4</sub> are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects, and steric effects, said tuning groups being selected from the group consisting of (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl, Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

G<sub>1</sub> is a bridging group to connect at least two conjugated rings to achieve a desired chromophore, said bridging group selected from the group consisting of (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons; and

W is an electron-withdrawing group for tuning reactivity of the maleic anhydride group of said molecular system, which enables said molecular system to undergo a smooth charge separation or recombination upon application of said electric field, said electron-withdrawing group selected from the group consisting of (a) carboxylic acid and its derivatives, (b) nitro, (c) nitrile, (d) ketone, (e) aldehyde, (f) sulfone, (g)

sulfuric acid and its derivatives, (h) hetero atoms selected from the group consisting of F, Cl, Br, N, O, and S, and (i) functional groups with at least one of said hetero atoms.

9. The switchable medium of Claim 6 wherein said molecular system comprises



where:

Q is a connecting unit between two phenyl rings and is selected from the group consisting of S, O, NH, NR, hydrocarbon, or substituted hydrocarbon;

5 Con<sub>1</sub> and Con<sub>2</sub> are optional connecting units between one molecule and another molecule or between a molecule and a solid substrate, said connecting units independently selected from the group consisting of: (a) hydrogen (utilizing a hydrogen bond), (b) multivalent hetero atoms selected from the group consisting of C, N, O, S, and P, (c) functional groups containing said hetero atoms, (d) saturated or unsaturated  
10 hydrocarbons, and (e) substituted hydrocarbons;

R<sub>1</sub> and R<sub>2</sub> are spacing groups, used to provide an appropriate 3-dimensional scaffolding to allow molecules to pack together while providing rotational space for a part of the molecule, said spacing groups being independently selected from the group consisting of: (a) hydrogen, (b) saturated or unsaturated hydrocarbons, and (c) substituted  
15 hydrocarbons;

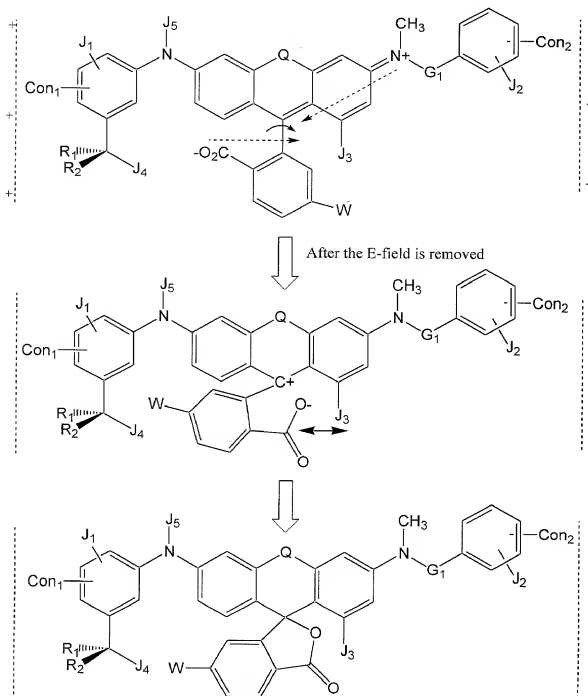
J<sub>1</sub>, J<sub>2</sub>, J<sub>3</sub>, J<sub>4</sub>, and J<sub>5</sub> are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects, and steric effects, said tuning groups being selected from the group consisting of (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl,  
20 Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

G<sub>1</sub> is a bridging group to connect at least two conjugated rings to achieve a desired chromophore, said bridging group selected from the group consisting of (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups  
25 with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons; and

W is an electron-withdrawing group for tuning reactivity of the maleic anhydride group of said molecular system, which enables said molecular system to undergo a smooth charge separation or recombination upon application of said electric field,  
30 said electron-withdrawing group selected from the group consisting of (a) carboxylic acid and its derivatives, (b) nitro, (c) nitrile, (d) ketone, (e) aldehyde, (f) sulfone, (g)

sulfuric acid and its derivatives, (h) hetero atoms selected from the group consisting of F, Cl, Br, N, O, and S, and (i) functional groups with at least one of said hetero atoms.

10. The switchable medium of Claim 6 wherein said molecular system  
5 comprises



where:

Q is a connecting unit between two phenyl rings and is selected from the group consisting of S, O, NH, NR, hydrocarbon, or substituted hydrocarbon;

Con<sub>1</sub> and Con<sub>2</sub> are optional connecting units between one molecule and another molecule or between a molecule and a solid substrate, said connecting units independently selected from the group consisting of: (a) hydrogen (utilizing a hydrogen bond), (b) multivalent hetero atoms selected from the group consisting of C, N, O, S, and P, (c) functional groups containing said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

R<sub>1</sub> and R<sub>2</sub> are spacing groups, used to provide an appropriate 3-dimensional scaffolding to allow molecules to pack together while providing rotational space for a part of the molecule, said spacing groups being independently selected from the group consisting of: (a) hydrogen, (b) saturated or unsaturated hydrocarbons, and (c) substituted hydrocarbons;

J<sub>1</sub>, J<sub>2</sub>, J<sub>3</sub>, J<sub>4</sub>, and J<sub>5</sub> are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects, and steric effects, said tuning groups being selected from the group consisting of (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl, Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

G<sub>1</sub> is a bridging group to connect at least two conjugated rings to achieve a desired chromophore, said bridging group selected from the group consisting of (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons; and

W is an electron-withdrawing group for tuning reactivity of the maleic anhydride group of said molecular system, which enables said molecular system to undergo a smooth charge separation or recombination upon application of said electric field, said electron-withdrawing group selected from the group consisting of (a) carboxylic acid and its derivatives, (b) nitro, (c) nitrile, (d) ketone, (e) aldehyde, (f) sulfone, (g)

sulfuric acid and its derivatives, (h) hetero atoms selected from the group consisting of F, Cl, Br, N, O, and S, and (i) functional groups with at least one of said hetero atoms.

11. The switchable medium of Claim 1 wherein said molecular system is bi-  
5 stable, which provides a non-volatile component.

12. The switchable medium of Claim 1 wherein said molecular system has es-  
sentially a low activation barrier between different states to provide a fast, but volatile,  
switch.  
10

13. The switchable medium of Claim 1 wherein said molecular system has more  
than two switchable states, such that optical properties of said molecular system can be  
tuned by either continuously by application of a decreasing or increasing electric field to  
form a volatile switch or the color is changed abruptly by the application of voltage  
15 pulses to a switch with at least one activation barrier.

14. The switchable medium of Claim 1 wherein said molecular system changes  
between a transparent state and a colored state.

15. The switchable medium of Claim 1 wherein said molecular system changes  
20 between one colored state and another colored state.

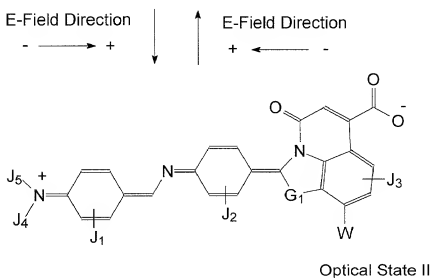
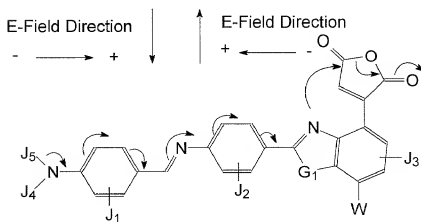
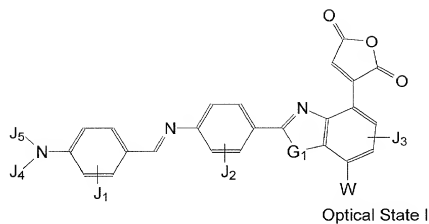
16. An electronic ink including an electric field activated molecular system con-  
figured within an electric field generated by a pair of electrodes, said molecular system  
25 having an electric field induced band gap change that occurs via a reversible or irre-  
versible change of extent of the electron conjugation in the molecule via chemical  
bonding change to change the band gap, wherein in a first state, there is substantial  
conjugation throughout the molecular system, resulting in a relatively smaller band gap,  
and wherein in a second state, the substantial conjugation is destroyed, resulting in a  
30 relatively larger band gap.

17. The electronic ink of Claim 16 wherein said change of substantial conjugation is accomplished by charge separation or recombination accompanied by increasing or decreasing molecular electronic state localization.

5 18. The electronic ink of 17 wherein said molecular system comprises

19. The electronic ink of 18 wherein said molecular system comprises





where:

$J_1$ ,  $J_2$ ,  $J_3$ ,  $J_4$  and  $J_5$  are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects,

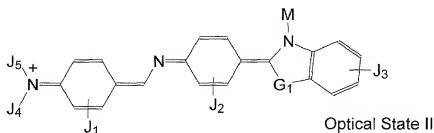
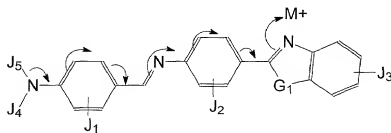
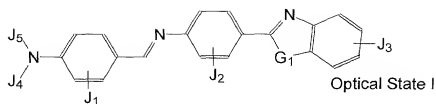
and steric effects, said tuning groups being selected from the group consisting of (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl, Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

5        G<sub>1</sub> is a bridging group to connect at least two conjugated rings to achieve a desired chromophore, said bridging group selected from the group consisting of (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons; and

10        W is an electron-withdrawing group for tuning reactivity of the maleic anhydride group of said molecular system, which enables said molecular system to undergo a smooth charge separation or recombination upon application of said electric field, said electron-withdrawing group selected from the group consisting of (a) carboxylic acid and its derivatives, (b) nitro, (c) nitrile, (d) ketone, (e) aldehyde, (f) sulfone, (g) sulfuric acid and its derivatives, (h) hetero atoms selected from the group consisting of F, Cl, Br, N, O, and S, and (i) functional groups with at least one of said hetero atoms.

15

19. The electronic ink of Claim 17 wherein said molecular system comprises



where:

- 5  $J_1, J_2, J_3, J_4$  and  $J_5$  are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects, and steric effects, said tuning groups being selected from the group consisting of (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl, Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

- 10  $G_1$  is a bridging group to connect at least two conjugated rings to achieve a desired chromophore, said bridging group selected from the group consisting of (a) het-

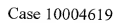
ero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons; and

5  $M^+$  is selected from the group consisting of transition metals, their halogen complexes,  $H^+$ , and Lewis acids.

10 20. The switchable medium of Claim 16 wherein said change of substantial conjugation is accomplished by change of extent of the conjugation of the molecular electronic states via charge separation or recombination and  $\pi$ -bond breaking or making.

15 21. The switchable medium of Claim 20 wherein said molecular system includes a C-O bond of a lactone that is labile enough and can undergo a bond breaking or making in the presence of an applied electric field, thereby inducing said change of the electron conjugation via chemical bonding change to change the band gap.

22. The switchable medium of Claim 21 wherein said molecular system comprises



where:

Q is a connecting unit between two phenyl rings and is selected from the group consisting of S, O, NH, NR, hydrocarbon, or substituted hydrocarbon;

Con<sub>1</sub> and Con<sub>2</sub> are optional connecting units between one molecule and another molecule or between a molecule and a solid substrate, said connecting units independently selected from the group consisting of: (a) hydrogen (utilizing a hydrogen bond), (b) multivalent hetero atoms selected from the group consisting of C, N, O, S, and P, (c) functional groups containing said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

R<sub>1</sub> and R<sub>2</sub> are spacing groups, used to provide an appropriate 3-dimensional scaffolding to allow molecules to pack together while providing rotational space for a part of the molecule, said spacing groups being independently selected from the group consisting of: (a) hydrogen, (b) saturated or unsaturated hydrocarbons, and (c) substituted hydrocarbons;

J<sub>1</sub>, J<sub>2</sub>, J<sub>3</sub>, and J<sub>4</sub> are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects, and steric effects, said tuning groups being selected from the group consisting of (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl, Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

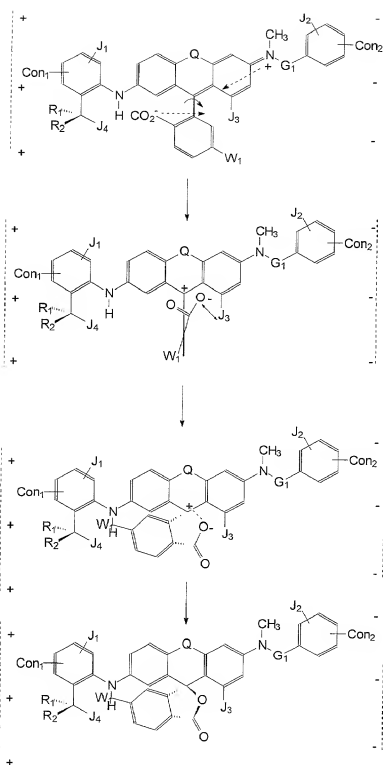
G<sub>1</sub> is a bridging group to connect at least two conjugated rings to achieve a desired chromophore, said bridging group selected from the group consisting of (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons; and

W is an electron-withdrawing group for tuning reactivity of the maleic anhydride group of said molecular system, which enables said molecular system to undergo a smooth charge separation or recombination upon application of said electric field, said electron-withdrawing group selected from the group consisting of (a) carboxylic acid and its derivatives, (b) nitro, (c) nitrile, (d) ketone, (e) aldehyde, (f) sulfone, (g)

sulfuric acid and its derivatives, (h) hetero atoms selected from the group consisting of F, Cl, Br, N, O, and S, and (i) functional groups with at least one of said hetero atoms.

23. The electronic ink of Claim 21 wherein said molecular system comprises

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where:

Q is a connecting unit between two phenyl rings and is selected from the group consisting of S, O, NH, NR, hydrocarbon, or substituted hydrocarbon;

Con<sub>1</sub> and Con<sub>2</sub> are optional connecting units between one molecule and another molecule or between a molecule and a solid substrate, said connecting units independently selected from the group consisting of: (a) hydrogen (utilizing a hydrogen bond), (b) multivalent hetero atoms selected from the group consisting of C, N, O, S, and P, (c) functional groups containing said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

R<sub>1</sub> and R<sub>2</sub> are spacing groups, used to provide an appropriate 3-dimensional scaffolding to allow molecules to pack together while providing rotational space for a part of the molecule, said spacing groups being independently selected from the group consisting of: (a) hydrogen, (b) saturated or unsaturated hydrocarbons, and (c) substituted hydrocarbons;

J<sub>1</sub>, J<sub>2</sub>, J<sub>3</sub>, and J<sub>4</sub> are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects, and steric effects, said tuning groups being selected from the group consisting of (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl, Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

G<sub>1</sub> is a bridging group to connect at least two conjugated rings to achieve a desired chromophore, said bridging group selected from the group consisting of (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons; and

W is an electron-withdrawing group for tuning reactivity of the maleic anhydride group of said molecular system, which enables said molecular system to undergo a smooth charge separation or recombination upon application of said electric field, said electron-withdrawing group selected from the group consisting of (a) carboxylic acid and its derivatives, (b) nitro, (c) nitrile, (d) ketone, (e) aldehyde, (f) sulfone, (g)

5

The diagram illustrates the formation of a photoinduced charge transfer complex (CTC) from a neutral molecule and a photoacid. The process is shown in three stages, separated by upward arrows.

**Top Stage (Neutral Molecule):** A molecule consisting of a central triphenylamine core (labeled Q) substituted with a phenyl group (J<sub>3</sub>) and a carboxylate group (-O<sub>2</sub>C). The phenyl group is further substituted with a substituent W. The molecule is also substituted with two N-phenyl groups (J<sub>1</sub> and J<sub>2</sub>) and a methyl group (CH<sub>3</sub>). The N-phenyl groups are further substituted with a substituent Con<sub>1</sub> and a substituent Con<sub>2</sub>. The methyl group is further substituted with a substituent G<sub>1</sub>. The molecule is also substituted with a substituent R<sub>1</sub> and a substituent R<sub>2</sub>.

**Middle Stage (Photoinduced CTC):** The molecule is shown in a photoinduced charge transfer complex (CTC) state. The central triphenylamine core (labeled Q) is now positively charged (Q<sup>+</sup>). The carboxylate group (-O<sub>2</sub>C) is now a carboxylic acid group (-COOH). The phenyl group (J<sub>3</sub>) is now a phenyl cation (J<sub>3</sub><sup>+</sup>). The N-phenyl groups (J<sub>1</sub> and J<sub>2</sub>) and the methyl group (CH<sub>3</sub>) are still present. The substituents Con<sub>1</sub>, Con<sub>2</sub>, G<sub>1</sub>, R<sub>1</sub>, and R<sub>2</sub> are also present. Dashed lines indicate the interaction between the positive charge on the central core and the negative charge on the carboxylic acid group, and between the positive charge on the phenyl group and the negative charge on the carboxylic acid group.

**Bottom Stage (Neutral Molecule):** The molecule is shown in a neutral state after the photoinduced CTC has been formed. The central triphenylamine core (labeled Q) is neutral. The carboxylic acid group (-COOH) is now a carboxylate group (-COO<sup>-</sup>). The phenyl group (J<sub>3</sub>) is now a phenyl anion (J<sub>3</sub><sup>-</sup>). The N-phenyl groups (J<sub>1</sub> and J<sub>2</sub>) and the methyl group (CH<sub>3</sub>) are still present. The substituents Con<sub>1</sub>, Con<sub>2</sub>, G<sub>1</sub>, R<sub>1</sub>, and R<sub>2</sub> are also present.

The text "An external E-field is applied" is written below the middle stage, indicating the condition for the formation of the CTC.

where:

Q is a connecting unit between two phenyl rings and is selected from the group consisting of S, O, NH, NR, hydrocarbon, or substituted hydrocarbon;

Con<sub>1</sub> and Con<sub>2</sub> are optional connecting units between one molecule and another molecule or between a molecule and a solid substrate, said connecting units independently selected from the group consisting of: (a) hydrogen (utilizing a hydrogen bond), (b) multivalent hetero atoms selected from the group consisting of C, N, O, S, and P, (c) functional groups containing said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

R<sub>1</sub> and R<sub>2</sub> are spacing groups, used to provide an appropriate 3-dimensional scaffolding to allow molecules to pack together while providing rotational space for a part of the molecule, said spacing groups being independently selected from the group consisting of: (a) hydrogen, (b) saturated or unsaturated hydrocarbons, and (c) substituted hydrocarbons;

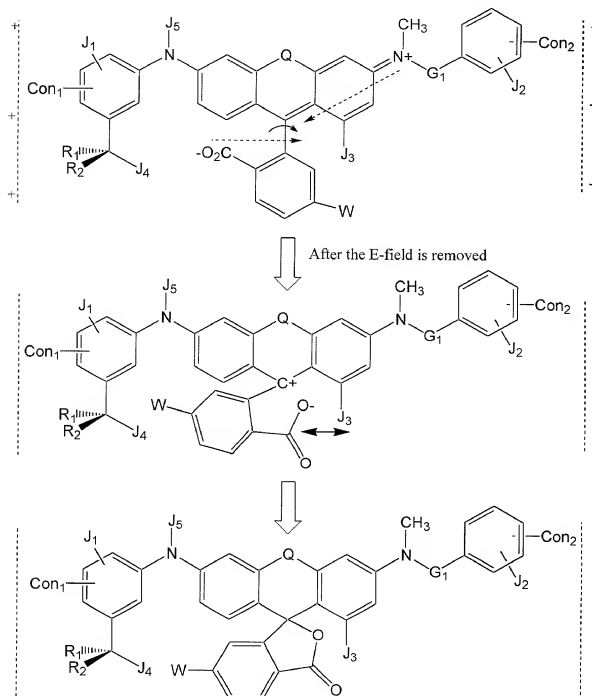
J<sub>1</sub>, J<sub>2</sub>, J<sub>3</sub>, J<sub>4</sub>, and J<sub>5</sub> are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects, and steric effects, said tuning groups being selected from the group consisting of (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl, Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

G<sub>1</sub> is a bridging group to connect at least two conjugated rings to achieve a desired chromophore, said bridging group selected from the group consisting of (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons; and

W is an electron-withdrawing group for tuning reactivity of the maleic anhydride group of said molecular system, which enables said molecular system to undergo a smooth charge separation or recombination upon application of said electric field, said electron-withdrawing group selected from the group consisting of (a) carboxylic acid and its derivatives, (b) nitro, (c) nitrile, (d) ketone, (e) aldehyde, (f) sulfone, (g)

sulfuric acid and its derivatives, (h) hetero atoms selected from the group consisting of F, Cl, Br, N, O, and S, and (i) functional groups with at least one of said hetero atoms.

25. The electronic ink of Claim 21 wherein said molecular system comprises



where:

Q is a connecting unit between two phenyl rings and is selected from the group consisting of S, O, NH, NR, hydrocarbon, or substituted hydrocarbon;

Con<sub>1</sub> and Con<sub>2</sub> are optional connecting units between one molecule and another molecule or between a molecule and a solid substrate, said connecting units independently selected from the group consisting of: (a) hydrogen (utilizing a hydrogen bond), (b) multivalent hetero atoms selected from the group consisting of C, N, O, S, and P, (c) functional groups containing said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

R<sub>1</sub> and R<sub>2</sub> are spacing groups, used to provide an appropriate 3-dimensional scaffolding to allow molecules to pack together while providing rotational space for a part of the molecule, said spacing groups being independently selected from the group consisting of: (a) hydrogen, (b) saturated or unsaturated hydrocarbons, and (c) substituted hydrocarbons;

J<sub>1</sub>, J<sub>2</sub>, J<sub>3</sub>, J<sub>4</sub>, and J<sub>5</sub> are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects, and steric effects, said tuning groups being selected from the group consisting of (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl, Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

G<sub>1</sub> is a bridging group to connect at least two conjugated rings to achieve a desired chromophore, said bridging group selected from the group consisting of (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons; and

W is an electron-withdrawing group for tuning reactivity of the maleic anhydride group of said molecular system, which enables said molecular system to undergo a smooth charge separation or recombination upon application of said electric field, said electron-withdrawing group selected from the group consisting of (a) carboxylic acid and its derivatives, (b) nitro, (c) nitrile, (d) ketone, (e) aldehyde, (f) sulfone, (g)

sulfuric acid and its derivatives, (h) hetero atoms selected from the group consisting of F, Cl, Br, N, O, and S, and (i) functional groups with at least one of said hetero atoms.

26. The electronic ink of Claim 16 wherein said molecular system is bi-stable,  
5 which provides a non-volatile component.

27. The electronic ink of Claim 16 wherein said molecular system has essentially  
a low activation barrier between different states to provide a fast, but volatile, switch.

10 28. The electronic ink of Claim 16 wherein said molecular system has more than  
two switchable states, such that optical properties of said molecular system can be tuned  
by either continuously by application of a decreasing or increasing electric field to form  
a volatile switch or the color is changed abruptly by the application of voltage pulses to a  
switch with at least one activation barrier.

15 29. The electronic ink of Claim 16 wherein said molecular system changes  
between a transparent state and a colored state.

20 30. The electronic ink of Claim 16 wherein said molecular system changes  
between one colored state and another colored state.